Biophysical Setting - Northern Colorado Plateau Network Park Units

Structural Geology and Topography

All but three NCPN units are within the Colorado Plateau Physiographic Province. TICA is located in the Middle Rocky Mountains Province, FOBU in the Wyoming Basin Province, and GOSP in the Basin and Range Province (Hunt 1974). Like the Colorado Plateau, larger units of the NCPN are characterized by striking structural geology—extensive areas of nearly horizontal sedimentary formations possessing diverse physical and chemical characteristics, great upwarps that form dramatic topographic and geomorphic features, and numerous basalt-capped mesas and plateaus. If there is a single theme that unifies the Colorado Plateau as a region, it is structural geology. Ecological patterns and processes are profoundly shaped by widespread exposures of geologic strata that repeat themselves across the Plateau (Table 1). Of the NCPN units DINO, CARE, and ARCH are the most diverse geologically. Many sedimentary strata are common to ARCH, CANY, CARE, COLM, DINO, and ZION.

Elevation, topographic relief, and topographic variability are additional factors that strongly influence patterns of life in NCPN units. Across the entire network, elevation ranges from 1112 m in ZION at the edge of the Mojave Desert, to 3247 m at CEBR (Table 2, Fig. 1). Vertical relief varies from 64 m at PISP to over 1500 m at ZION and CARE. Almost 50 percent of the network is lower than 1750 m (5740 ft)—a consequence of large expanses of low-elevation lands at CANY, CARE, ARCH, and ZION. Relatively high-elevation parks include CEBR, BRCA, BLCA, and CURE. The extreme topographic variability evident in these figures is associated with deeply incised drainage systems, massive vertical escarpments, and abruptly discontinuous environmental gradients that present significant challenges to design and implementation of field-based monitoring.

Climate

Climatic characteristics vary considerably among NCPN units. Based on long-term data collected by National Weather Service Cooperative Network stations at or near NCPN units, mean annual temperatures range from 1.9 °C near CEBR to 16.2 °C at ZION (Table 3). Mean annual precipitation at long-term stations ranges from 192 mm at CARE to 752 mm near CEBR. Spatial estimates of average annual precipitation from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) (http://www.ocs.orst.edu/prism/) provide a more-detailed representation of annual precipitation patterns across the network (Table 4). On the basis of model estimates, over 65 percent of network land area averages less than 300 mm of precipitation annually—emphasizing that aridity is a dominant feature the network.

The seasonal timing of precipitation in relation to evaporative demand is a key climatic characteristic affecting ecosystem structure and function (Walter 1979). The Colorado Plateau is divided roughly into two climatic regions by a broad, northeastward-trending boundary which extends diagonally from northwestern Arizona to northcentral Colorado (Mitchell 1976, Peterson 1994) (Fig. 2). This broad boundary coincides with the mean northwestern extent of summer precipitation associated with monsoonal circulation patterns carrying moisture from the Gulf of Mexico and the Gulf of California. Approximately two-thirds of the Plateau lies southeast of this climatic boundary and is characterized by a bimodal precipitation regime with both winter and summer maxima. The magnitude of the summer precipitation maximum generally weakens from southeast to northwest, and the northwestern one-third of the Plateau is dominated by winter precipitation.

Precipitation seasonality across the NCPN tends to vary in relation to the monsoon boundary that crosses the network area’s southeastern corner. Fig. 3 illustrates climate diagrams for NCPN parks. The four parks located farthest from the monsoon boundary (DINO, TICA, GOSP, and FOBU) show a late-summer dip in average monthly precipitation. Diagrams for other NCPN parks show relatively distinct peaks in average monthly precipitation attributable to monsoon moisture. In these parks, the strength of the summer monsoon signal generally increases with elevation. Although these parks are influenced by summer monsoon precipitation, there is considerable year-to-year variability in amount of monsoon precipitation received due to their location at the circulation pattern’s periphery. In association with global temperature changes over the next century, general circulation models predict changes in seasonal precipitation patterns across much of North America (Weltzin and McPherson2003). Ehleringer and colleagues (Ehleringer et al. 2000, Williams and Ehleringer 2000) have hypothesized that effects of global change on precipitation patterns and associated ecological processes may be seen relatively early on the Colorado Plateau due to its proximity to the monsoon boundary.

Table 1. Geologic units exposed in Northern Colorado Plateau Network Parks and monuments.

Age	Formation / deposit	ARCH	BLCA	BRCA	CANY	CARE	CEBR	COLM	CURE	DINO	FOBU	GOSP	HOVE	NABR	PISP	TICA	ZION
Quater-nary	Aeolian / alluvial deposits																
	Basalt / volcanics																
Tertiary	Basalt / volcanics																
	Browns Park Fm.																
	Bishop Cg.																
	Markagunt Megabreccia																
	Leach Canyon Fm.																
	Isom Fm.																
	Flagstaff Ls.																
	Conglomerate of Boat Mesa																
	Brian Head Fm.																
	Green River Fm.																
	Wasatch Fm.																
	Claron Fm.																
Cretaceous	Kaiparowits Fm.																
	Wahweap Fm.																
	Straight Cliffs Fm.																
	Mesaverde Fm.																
	Mancos/Tropic Sh.																
	Frontier Ss.																
	Mowry Sh.																
	Dakota Ss.																
	Cedar Mt. Fm.								Burro Canyon	Burro Canyon			Burro Canyon				
Jurassic	Morrison Fm.																
	Summerville Fm.									Wanakah							
	Curtis Fm.									Stump							
	Entrada Ss.																
	Carmel Fm.																
	Temple Cap Fm.																
	Page Ss.																
	Navajo Ss.									Glen Canyon							
	Kayenta Fm.																
	Moenave Fm.																
	Wingate Ss.																
Tri-assic	Chinle Fm.																
	Moenkopi Fm.																
Permian	Kaibab Ls.																
	Toroweap Fm.																
	Cutler Gp.													Cedar Mesa			
	Elephant Canyon Fm.																
	Park City Fm.																
Pennsylvanian	Oquirrh Fm.																
	Honaker Trail Fm.																
	Paradox Fm.																
	Weber Ss.																
	Morgan Fm.																
	Round Valley Ls.																
Missis-sipian	Doughnut Sh. / Humbug Fm.																
	Deseret Ls.																
	Madison Ls.																
Cam-brian	Misc. igneous and metamorphics																
	Lodore Fm.																
Pre-Cam-brian	Uinta Mt. Gp.																
	Misc. igneous and metamorphics																

Table 2. Elevation and topographic characteristics of Northern Colorado Plateau Network Parks and Monuments. Total hectares per management unit may vary slightly from those presented elsewhere in the document due to cumulative areal discrepancies in digital coverages.

Park	Elevation (m)		Relief	Hectares by elevation zone (m) (values in parentheses indicate percent of total area)									Total	Slope (deg.)	
code	min	max	(m)	1000-1250	1250-1500	1500-1750	1750-2000	2000-2250	2250-2500	2500-2750	2750-3000	3000-3250	(ha)	Mean	s.d.
ARCH	1,206	1,725	519	389 (1.3)	20,424 (65.9)	10,160 (32.8)							30,974 (100.0)	9.8	11.5
BLCA	1,636	2,752	1,116			270 (2.4)	1,360 (11.9)	2,567 (22.4)	5,180 (45.3)	2,059 (18.0)	2 (<0.1)		11,439 (100.0)	21.8	17.0
BRCA	2,000	2,777	777					3,926 (26.9)	7,367 (50.4)	3,297 (22.6)	23 (0.2)		14,613 (100.0)	17.5	12.3
CANY	1,140	2,189	1,049	9,725 (7.2)	49,730 (36.8)	58,256 (43.1)	16,802 (12.4)	689 (0.5)					135,201 (100.0)	17.6	16.1
CARE	1,182	2,730	1,548	227 (0.2)	4,112 (4.2)	23,717 (24.0)	47,585 (48.2)	20,958 (21.2)	1,867 (1.9)	183 (0.2)			98,650 (100.0)	18.1	14.7
CEBR	2,461	3,247	785						20 (0.8)	673 (27.1)	873 (35.2)	914 (36.9)	2,480 (100.0)	24.8	13.8
COLM	1,411	2,160	749		348 (4.2)	2,577 (31.2)	4,077 (49.4)	1,252 (15.2)					8,255 (100.0)	16.8	13.9
CURE	1,982	2,898	916				34 (0.2)	1,736 (10.5)	12,933 (77.9)	1,801 (10.8)	108 (0.6)		16,612 (100.0)	16.7	15.2
DINO	1,442	2,747	1,305		1,893 (2.2)	21,625 (24.8)	27,460 (31.5)	24,359 (27.9)	10,909 (12.5)	1,062 (1.2)			87,308 (100.0)	17.6	13.8
FOBU	2,012	2,466	454					2,189 (65.3)	1,164 (34.7)				3,353 (100.0)	10.5	6.9
GOSP	1,317	1,613	296		1,013 (94.2)	63 (5.8)							1,075 (100.0)	6.3	5.2
HOVE	1,548	2,056	508			262 (80.5)	6 (1.7)	58 (17.6)					326 (99.9)	6.4	6.3
NABR	1,702	2,019	318			67 (2.3)	2,862 (95.6)	63 (2.1)					2,993 (100.0)	12.6	13.0
PISP	1,495	1,559	64		2 (14.6)	14 (85.4)							16 (100.0)	6.1	6.8
TICA	1,669	2,452	783			23 (23.6)	38 (38.7)	25 (25.7)	12 (12.0)				98 (100.0)	37.8	12.9
ZION	1,112	2,661	1,549	1,239 (2.1)	8,857 (14.8)	12,232 (20.5)	21,852 (36.5)	12,081 (20.2)	3,408 (5.7)	144 (0.2)			59,813 (100.0)	26.3	18.4
Network	**1,112**	**3,247**	**2,134**	**11,589** (2.4)	**86,601** (18.2)	**129,625** (27.3)	**122,366** (25.8)	**70,139** (14.8)	**43,096** (9.1)	**9,299** (2.0)	**1,042** (0.2)	**951** (0.2)	**474,709** (100.0)		

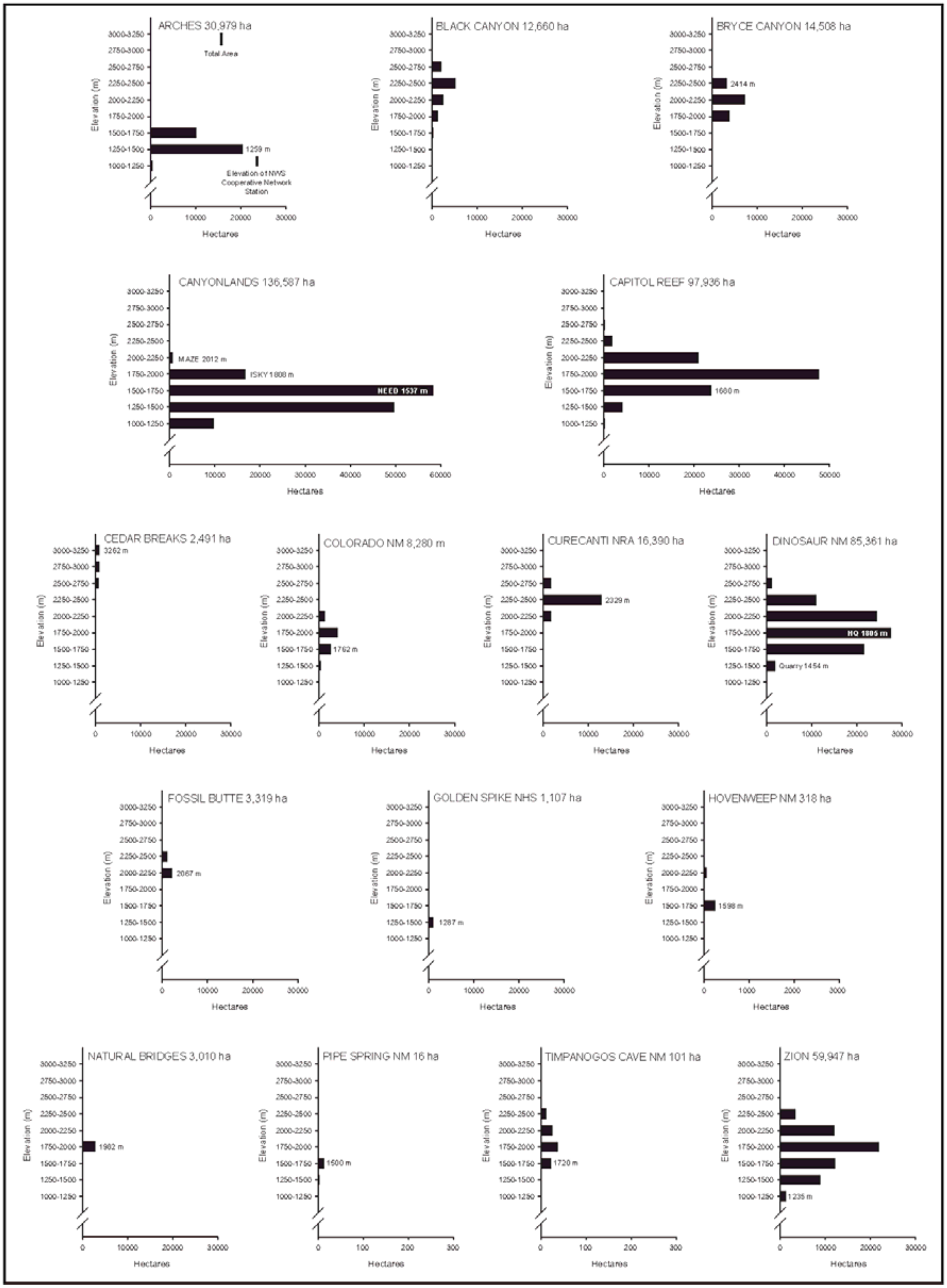


Figure 1. Elevation profiles of Northern Colorado Plateau Network parks. Note different x-axis scales for Hovenweep, Pipe Spring, and Timanogos Cave National Monuments. Elevations of National Weather Service Cooperative Network Climate Stations are indicated for each park.

Table 3. Selected climate data for National Weather Service (NWS) Cooperative Network stations at or near Northern Colorado Plateau Network Parks and Monuments. Values are averages based on data obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu/climsum.html). Seasons are defined ecologically following Comstock and Ehleringer (1992).

							Total precipitation							Mean temperature			
		Elevation	Latitude	Longitude	Period of	Years of	Annual	Oct-Feb		Mar-May		Jun-Sep		Annual	Oct-Feb	Mar-May	Jun-Sep
Park / District	NWS Station Name	(m)	(dd mm N)	(dd mm W)	Record	Record	(mm)	(mm)	(%)	(mm)	(%)	(mm)	(%)	(˚C)	(˚C)	(˚C)	(˚C)
ARCH	Arches NP	1259	38 37	109 37	5/80 - present	22	227	88	39	62	27	77	34	14.0	4.9	13.9	25.5
BRCA	Bryce Canyon NP	2412	37 39	112 10	6/59 - present	43	406	166	41	87	21	153	38	5.2	-1.6	3.8	14.6
CANY / ISKY	Canyonlands - The Neck	1808	38 27	109 49	6/65 - present	37	231	89	38	61	26	81	35	11.5	3.0	10.7	22.7
CANY / MAZE	Canyonlands - Hans Flat*	2012	38 15	110 10	10/80 - present	22	251	95	38	57	23	99	40	10.7	2.8	9.7	21.4
CANY / NEED	Canyonlands - The Needle	1537	38 09	109 45	6/65 - present	37	215	83	39	53	25	79	37	11.8	3.1	11.5	23.0
CARE	Capitol Reef NP	1680	38 17	111 16	4/67 - present	35	192	61	32	45	23	87	45	12.1	3.8	11.7	22.9
CEBR	Blowhard Mtn.*	3262	37 35	112 51	6/64 - present	38	752	331	44	228	30	194	26	1.9	-3.6	-0.6	10.7
COLM	Colorado NM	1762	39 06	108 44	8/48 - present	54	283	111	39	76	27	96	34	11.1	2.5	10.3	22.3
CURE	Blue Mesa Lake	2329	38 28	107 10	9/67 - present	35	243	100	41	39	16	104	43	4.8	-3.8	4.5	15.9
DINO / HQ	Dinosaur NM	1805	40 14	108 58	6/65 - present	37	302	106	35	88	29	107	35	8.4	-0.6	8.0	19.9
DINO / QUAR	Dinosaur NM Quarry Area	1454	40 26	109 18	4/58 - present	44	219	86	39	60	27	73	33	8.8	-1.2	9.3	20.9
FOBU	Fossil Butte	2067	41 50	110 46	8/90 - present	12	281	110	39	75	27	96	34	3.9	-4.1	3.4	14.3
GOSP	Corinne*	1287	41 33	112 07	7/48 - present	54	388	177	46	124	32	87	23	9.5	1.1	8.9	20.3
HOVE	Hovenweep NM	1598	37 23	109 05	12/55 - present	47	285	134	47	66	23	84	30	10.9	2.6	10.2	21.7
NABR	Natural Bridges NM	1982	37 37	109 59	6/65 - present	37	319	132	41	69	22	118	37	10.3	2.6	9.1	20.8
PISP	Pipe Spring NM	1500	36 52	112 44	6/63 - present	39	278	125	45	62	22	91	33	12.6	5.5	11.5	22.3
TICA	Timpanogos Cave	1720	40 27	111 42	7/48 - present	54	634	284	45	204	32	147	23	9.6	1.5	8.5	20.3
ZION	Zion NP	1235	37 13	112 59	7/48 - present	54	380	179	47	98	26	104	27	16.2	8.9	14.8	26.5

*station not in park

Table 4. Distribution of Northern Colorado Plateau Network Park and Monument lands among average annual precipitation zones estimated by the PRISM model (http://www.ocs.orst.edu/prism/). Total hectares per management unit may vary slightly from those presented elsewhere in the document due to cumulative areal discrepancies in digital coverages.

Park code	Hectares by precipitation zone (mm) (values in parentheses indicate percent of total area)																	Total (ha)
	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800	800-850	850-900	900-950	950-1000	
ARCH		30,090 (97.2)	878 (2.8)															30,968 (100.0)
BLCA				710 (5.9)	3,811 (31.8)	3,944 (32.9)	3,517 (29.4)											11,982 (100.0)
BRCA				4,193 (28.7)	6,890 (47.1)	3,535 (24.2)												14,619 (100.0)
CANY	18,389 (13.6)	96,552 (71.5)	16,558 (12.3)	3,461 (2.6)	39 (0.0)													134,999 (100.0)
CARE	48,140 (48.9)	44,886 (45.6)	4,598 (4.7)	507 (0.5)	252 (0.3)	158 (0.2)	0 (0.0)											98,542 (100.0)
CEBR												256 (10.4)	586 (23.8)	797 (32.3)	522 (21.1)	306 (12.4)	1 (0.0)	2,469 (100.0)
COLM		174 (2.1)	3,286 (39.7)	3,708 (44.8)	1,102 (13.3)													8,270 (100.0)
CURE			2,983 (15.0)	4,872 (24.5)	2,607 (13.1)	2,422 (12.2)	5,400 (27.2)	1,145 (5.8)	421 (2.1)									19,850 (100.0)
DINO		17,482 (20.1)	33,150 (38.0)	29,257 (33.6)	7,174 (8.2)	122 (0.1)												87,185 (100.0)
FOBU				582 (17.4)	1,150 (34.3)	788 (23.5)	779 (23.3)	50 (1.5)										3,348 (100.0)
GOSP				238 (22.1)	841 (78.0)													1,079 (100.0)
HOVE			211 (64.6)	58 (17.7)	57 (17.6)													326 (100.0)
NABR				2,993 (100.0)														2,993 (100.0)
PISP			16 (100.0)															16 (100.0)
TICA										1 (0.6)	70 (69.8)	30 (29.5)						100 (100.0)
ZION			2,764 (4.6)	5,557 (9.3)	20,085 (33.6)	27,100 (45.3)	2,752 (4.6)	1,573 (2.6)	19 (0.0)									59,851 (100.0)
NCPN	66,529 (14.0)	189,184 (39.7)	64,445 (13.5)	56,136 (11.8)	44,008 (9.2)	38,070 (8.0)	12,447 (2.6)	2,768 (0.6)	440 (0.1)	1 (0.0)	70 (0.0)	285 (0.1)	586 (0.1)	797 (0.2)	522 (0.1)	306 (0.1)	1 (0.0)	476,596 (100.0)

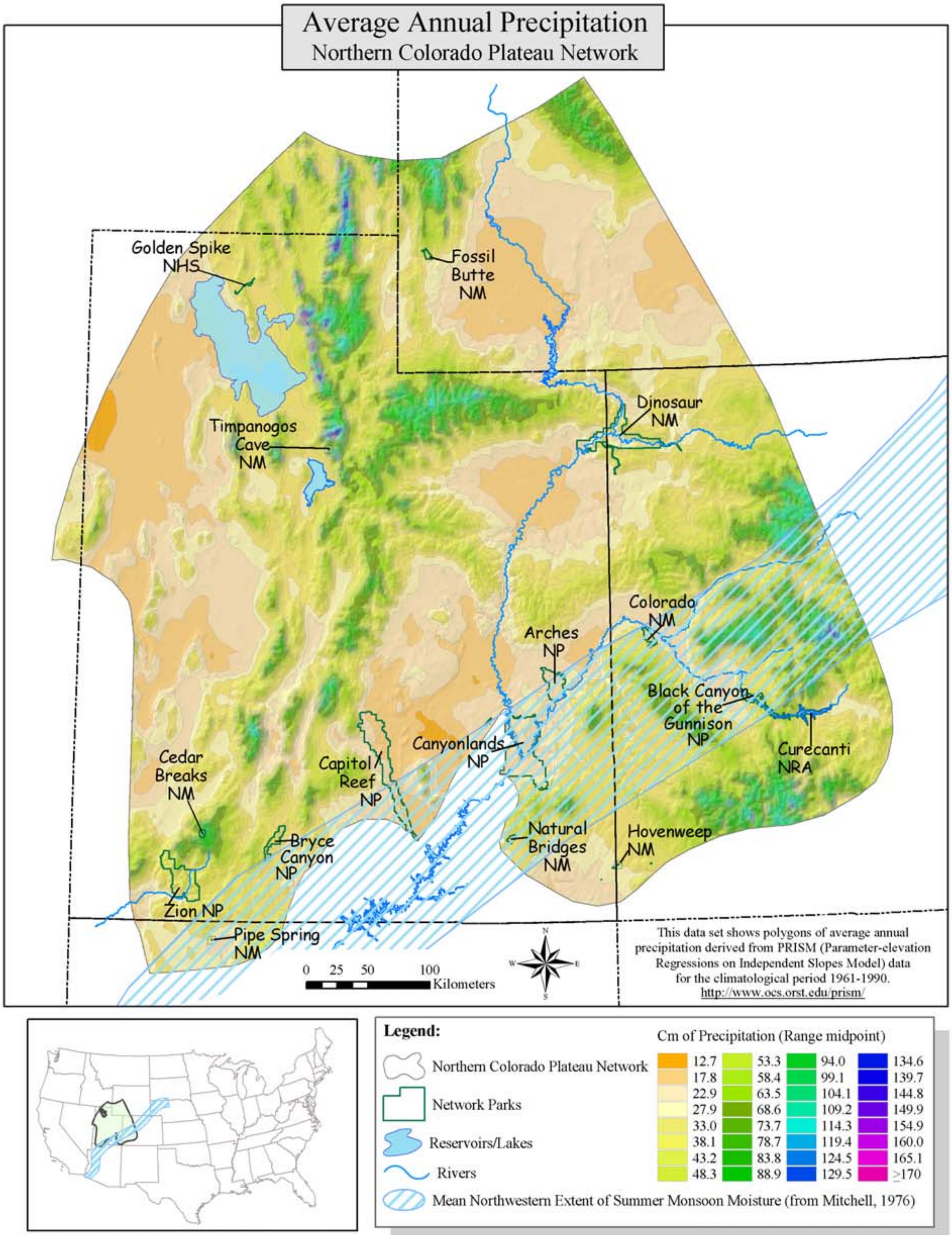


Figure 2. Average annual precipitation, Northern Colorado Plateau Network.

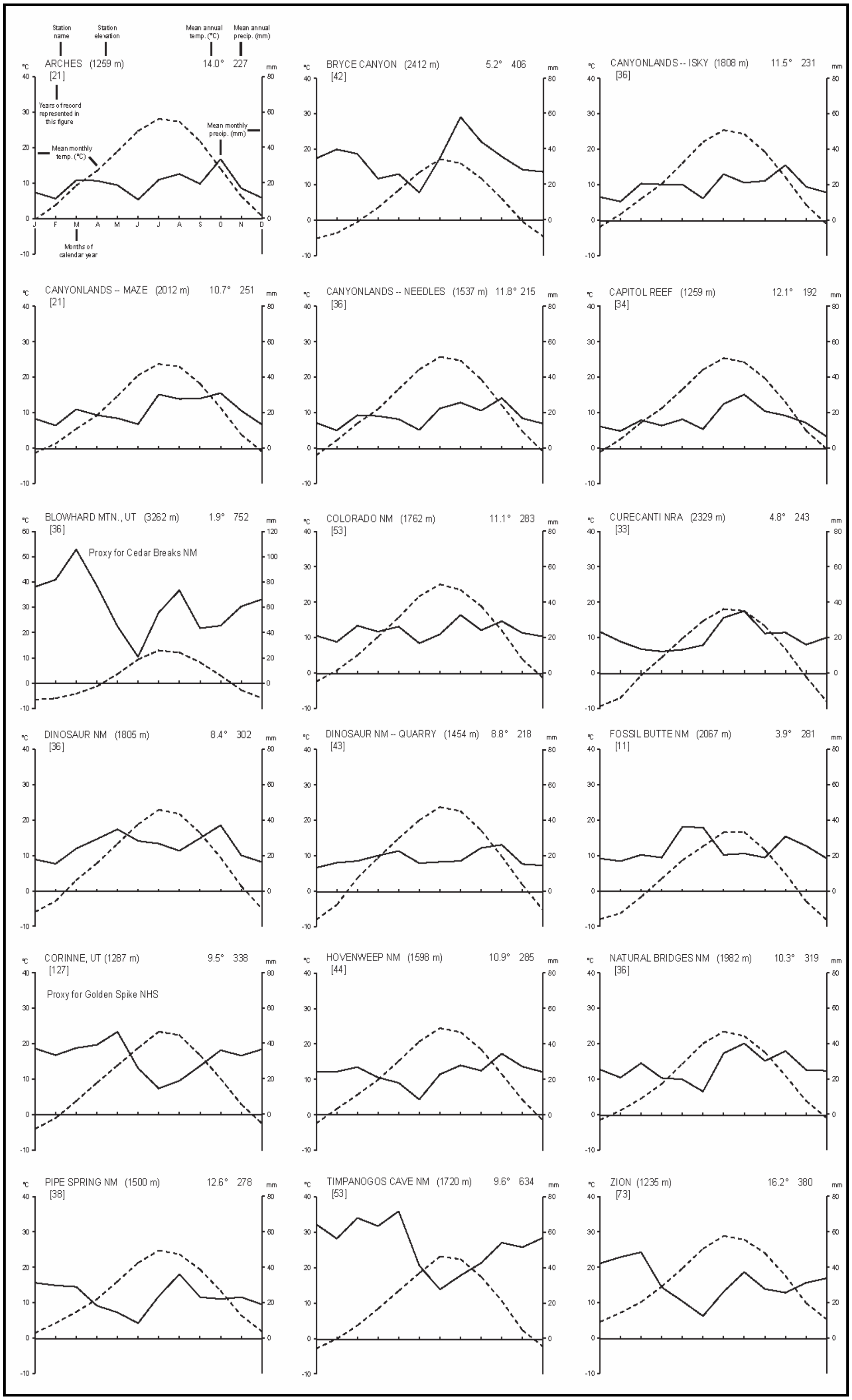


Figure 3. Climate diagrams for Northern Colorado Plateau Network Parks. Data were collected at National Weather Service Cooperative Network Stations and acquired from the Western Regional Climate Center (http://www.wrcc.dri.edu/climsum.html).

Ecological Units

Ecoregions

The National Hierarchical Framework of Ecological Units developed by the U.S. Forest Service (ECOMAP 1993, Bailey et al. 1994, McNab and Avers 1994) provides a useful means of integrating factors such as regional physiography and climate to assess broad-scale differences and similarities among NCPN parks. Ecological units within this multi-scale hierarchy also are referred to as “ecoregions” following Bailey (Bailey et al. 1994, Bailey 1995). Units in the hierarchy are designed on the basis of similar 1) potential natural communities, 2) soils, 3) hydrologic function, 4) landforms and topography, 5) lithology, 6) climate, and 7) ecological processes such as nutrient cycling, productivity, and natural disturbance regimes (Cleland et al. 1997). The relative importance of these factors in classification varies in relation to the spatial scale of units.

NCPN parks and monuments are located within five provinces of the national hierarchy (Fig. 4, Table 5). Most NCPN units are included in sections of the semidesert and desert provinces, reflecting the dominance of arid and semiarid conditions in the NCPN. Notably, four of the five prototype parks are located in a single section—the Northern Canyonlands Section of the Intermountain Semidesert & Desert Province. This suggests that some research and protocol development in non-prototype parks may be warranted to fully meet network needs.

Ecosystems

As a consequence of variations in substrate, topography, and climate, NCPN units support a wide range of ecosystems. On the basis of functional similarities, NCPN staff have grouped these into five broad categories, 1) unique ecosystems such as orchards, caves, and mines; 2) sparsely vegetated terrestrial ecosystems; 3) arid-semiarid shrubland, grassland, and woodland ecosystems; 4) montane shrubland, coniferous woodland, and forest ecosystems; and 5) riparian and wetland and aquatic ecosystems (Table 6). The last four of these are described briefly below, emphasizing the dominant vegetation. Plant species nomenclature follows Welsh et al. (1993).

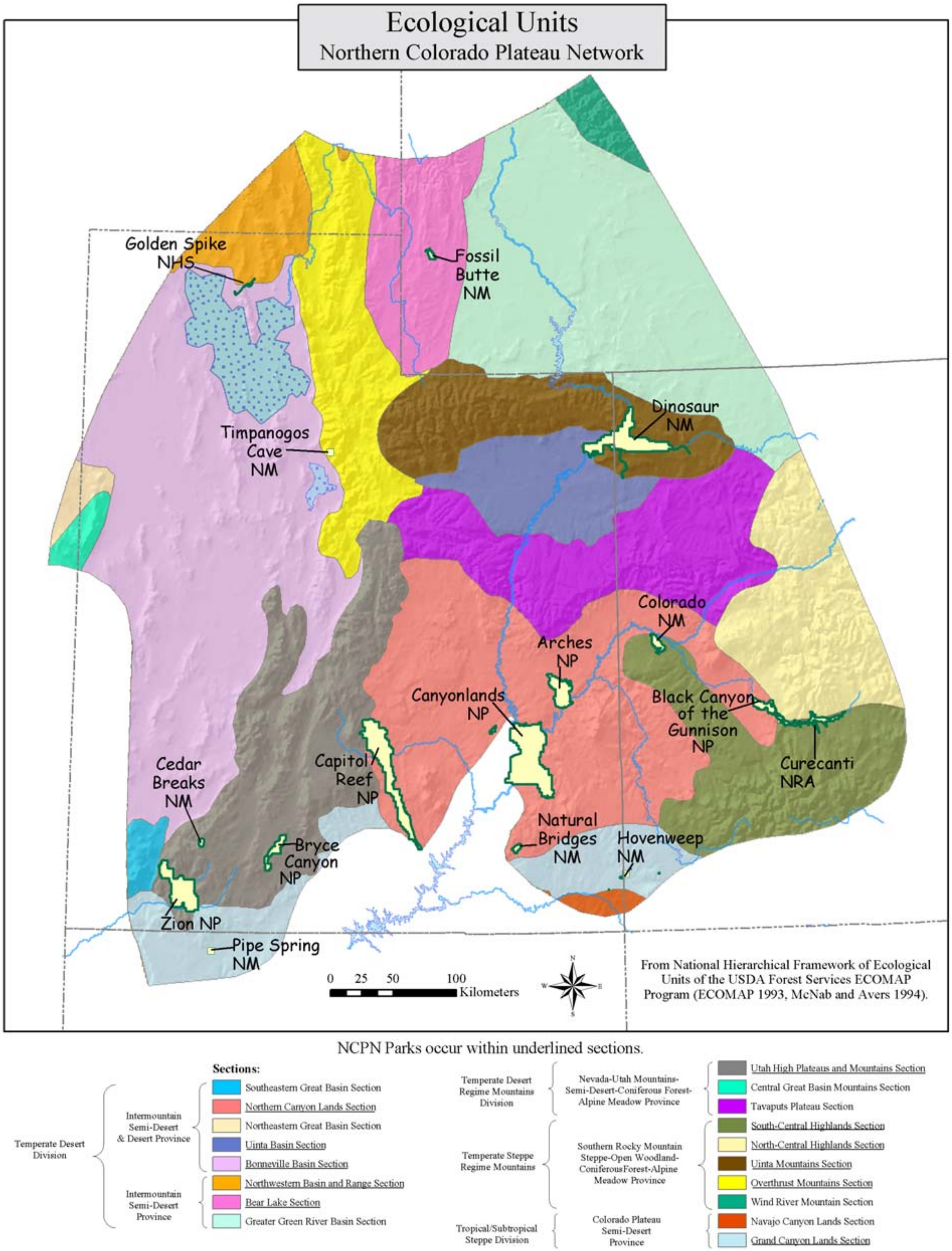


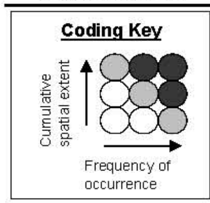
Figure 4. Ecological units of the Northern Colorado Plateau Network.

Table 5. Placement of Northern Colorado Plateau Network Parks and Monuments within the national hierarchical framework of ecological units of the USDA Forest Service's ECOMAP program (ECOMAP 1993, McNab and Avers 1994). All divisions listed are located within the Dry Domain.

Division (code) ***Province (code)*** *Section*	ARCH	BLCA	BRCA	CANY	CARE	CEBR	COLM	CURE	DINO	FOBU	GOSP	HOVE	NABR	PISP	TICA	ZION
Temperate Desert Division (340)																
Intermountain Semidesert & Desert Province (341)																
Northern Canyonlands Section	X	X		X	X			X					X			
Uinta Basin Section									X							
Bonneville Basin Section											X					
Intermountain Semidesert Province (342)																
Northwestern Basin and Range Section											X					
Bear Lake Section										X						
Tropical / Subtropical Steppe Division (310)																
Colorado Plateau Semidesert Province (313)																
Grand Canyon Lands Section												X		X		
Temperate Steppe Regime Mountains (M330)																
Southern Rocky Mountain Steppe - Open Woodland - Coniferous Forest - Alpine Meadow Province (M331)																
South-Central Highlands Section							X	X								
North-Central Highlands Section		X						X								
Uinta Mountains Section									X							
Overthrust Mountains Section															X	
Temperate Desert Regime Mountains Division (M340)																
Nevada -Utah Mountains - Semidesert - Coniferous Forest - Alpine Meadow Province (M341)																
Utah High Plateaus and Mountains Section			X			X										X

Table 6. Relative occurrence of major terrestrial, riparian, wetland and aquatic ecosystems with NCPN units. See Coding Key (below) for explanation of table entries.

Ecosystem category	NCPN units															
Ecosystems	ARCH	BLCA	BRCA	CANY	CARE	CEBR	COLM	CURE	DINO	FOBU	GOSP	HOVE	NABR	PISP	TICA	ZION
Riparian-wetland and aquatic ecosystems (combined)																
Lotic systems																
Rivers with associated aquatic & riparian systems	◍	●		●	◍			○	●						○	●
Perennial streams with associated aquatic & riparian systems				◍	○		○	◍	◍		○		◍			◍
Intermittent streams with associated aquatic & riparian systems	○		○	○	○		◍		◍	○		○	○			○
Lentic systems																
Reservoirs								●								
Perennial wetlands / marshes / wet meadows	○		○	○	○	○			○	○		○	○			○
Ephemeral playas / wetlands										○						○
Hanging gardens	◍	○		◍	○		○	○	○				◍	○		◍
Springs & seeps (other than hanging gardens)	○	○	◍	○	○	○	○	○	○	○		○	◍	○		○
Slickrock potholes / waterpockets	◍			●	◍		○		○		○		○			◍
Subalpine woodlands			○		○	◍										
Spruce-fir forests		○	◍			●		○							○	
Montane meadows / shrubland parks			◍			●										
Aspen woodlands / forests		○	○	○	○	○		○	○	◍						○
Douglas-fir woodlands / forests		○	◍	○	○	○	○	○	◍	◍			○		○	◍
Ponderosa pine woodlands / forests		○	◍	○	○	○		◍	◍				○			◍
Montane shrublands		●	○	○	○	○	◍	◍	◍	◍		○	◍		○	◍
Pinyon-juniper woodlands / savannas	●	●	◍	●	●	○	●	○	●		○	◍	●	○	○	●
Sagebrush shrublands / shrub steppe	○	◍	○	○	○		◍	●	●	●	●	●	○	○		◍
Greasewood shrublands / shrub steppe	○			○	◍		○		◍	○		○				○
Mixed grasslands / shrub steppe	◍			◍	◍		○		●	◍		○		○		◍
Shadscale dwarf-shrublands / shrub steppe	◍			●	●				◍		○	○	○			
Blackbrush shrublands / shrub steppe	●			●	○											○
Mat saltbush dwarf-shrublands / shrub steppe	○			◍	◍				○	○						
Shale-mudstone-siltstone badlands	○	○		○	●				◍	○						○
Claron breaks / limestone barrens			◍			●			○							
Rock-outcrop / slickrock	●			●	●		◍		●	○	○	○	○			◍
Cultivated orchards					○											
Caves and mines				○	○	○	○		○		○				●	



Sparsely Vegetated Terrestrial Ecosystems

These ecosystems are associated with bedrock exposures of shales, mudstones, siltstones, limestones, and sandstones. Vegetation is sparse because of physical and/or chemical traits of the substrate that strongly affect the availability of soil resources (e.g., saline shales and calcareous siltstones and mudstones), substrate stability (e.g., decomposing / eroding Claron limestone), and/or establishment opportunities (e.g., sandstone slickrock). Despite the barren appearance of these ecosystems, they frequently support unique communities consisting of rare and/or endemic plants (see discussion under *Floristic Distinctiveness* below). From a conservation perspective, the significance of these ecosystems greatly exceeds what would be expected on the basis of their productivity or standing biomass. Sparsely vegetated terrestrial ecosystems are extensive in many NCPN units. Such ecosystems are particularly significant both at CEBR and BRCA, where they are associated with the distinctive Claron Breaks.

Arid-Semiarid Shrubland, Grassland, and Woodland Ecosystems

The following descriptions of arid-semiarid ecosystems draw in part from the work of West and Young (2000) and are supplemented by observations and experience of NCPN staff.

-Mat Saltbush Dwarf Shrublands: dominated by perennial dwarf shrubs of the *Chenopodiaceae*, these ecosystems typically are associated with badland topography on shale substrates such as those associated with the Morrison, Mancos, or Tropic formations. *Atriplex corrugata* and *A. gardneri* var. *cuneata* are common dominants. This ecosystem is common but not extensive at CANY and CARE.

-Blackbrush Shrublands: dominated by the shrub *Coleogyne ramosissima*, this type usually is associated with residuum derived from calcareous geologic substrates, soils characterized by a shallow petrocalcic horizon, or with carbonate-stabilized sand dunes. With the exception of occasional *Ephedra* spp., *Gutierrezia* spp., and *Opuntia* spp., other woody plants are uncommon in blackbrush shrublands. Common herbaceous species include the grasses *Hilaria jamesii*, *Stipa hymenoides*, and *Sporobolus* spp. Relative dominance generally shifts from blackbrush to perennial grasses along a gradient of increasing depth to the petrocalcic horizon or the underlying geologic substrate. Although blackbrush shrublands occur throughout much of the Colorado Plateau and Mojave Desert regions, the spatial extent of this ecosystem is greatest in southeastern Utah. Blackbrush ecosystems are extensive landscape dominants at ARCH and CANY.

-Shadscale Dwarf Shrublands: dominated by the perennial dwarf shrub *Atriplex confertifolia*, this type tends to occur on shallow calcareous soils with higher clay and salt content than soils that support blackbrush. Perennial grasses such as *Sporobolus airoides*, *H. jamesii*, and *Stipa hymenoides* may co-dominate the vascular vegetation, depending on disturbance history. Shadscale-dominated ecosystems are most common at CANY, CARE, ARCH, and DINO.

-Mixed Grasslands / Shrub Steppe: in the Northern Canyonlands Section (Table 5), this type occurs on relatively deep, undeveloped sandy soils and is dominated by perennial grasses such as *Stipa comata*, *S. hymenoides*, *Hilaria jamesii*, *Bouteloua gracilis*, and *Aristida purpurea*. The dwarf-shrub *Gutierrezia* and the chenopod shrubs *Atriplex canescens* and *Ceratoides lanata* also are common. At higher elevations and latitudes, grasses such as *Elymus smithii*, *E. spicatus*, *E. lanceolatus*, *Festuca idahoensis*, and *Stipa thurberiana* increase in importance. To varying degrees, all shrubland ecosystems in NCPN units tend to intergrade with grassland vegetation in relation to disturbance history and soil characteristics. Grassland ecosystems are most common at DINO, CARE, CANY (Kleiner and Harper 1972, 1977), ARCH, and ZION. Nationwide, grasslands are among the most critically endangered ecosystem types because of cumulative losses to land-use activities (Noss et al. 1995). For this reason, healthy grassland ecosystems are among the most significant natural resources of NCPN units.

-Greasewood Shrublands: dominated by the perennial shrub *Sarcobatus vermiculatus*, this ecosystem typically is associated with saline basins and riparian terraces—frequently in association with a relatively high ground water table. Shrubs such as *Artemisia tridentata* var. *tridentata*, *Chrysothamnus nauseousus*, and *Suaeda* spp. may co-dominate. Typical herbaceous components include grasses *Distichlis* spp., *Sporobolus airoides*, *Elymus cinereus*, and forbs (both exotic) *Halogeton glomeratus* and *Salsola* spp. Greasewood ecosystems occur in most NCPN units, but they typically are minor landscape elements except at CARE and DINO.
-Sagebrush Shrublands: dominated by varieties of *Artemisia tridentata*. West and Young (2000) differentiated sagebrush ecosystems into major two types:
1) Great Basin sagebrush, found throughout all but the northernmost portions of the Colorado Plateau and NCPN; and
2) Sagebrush steppe, found at higher latitudes and elevations than Great Basin sagebrush.
In the former, sagebrush typically accounts for greater than 70 percent of live vascular plant cover, with *Chrysothamnus* spp. and *Elymus elymoides* as the most common co-occurring shrubs and grasses, respectively. As suggested by the name, the comparatively mesic sagebrush steppe usually is co-dominated by perennial grasses such as *Elymus smithii*, *E. spicatus*, *E. lanceolatus*, *Festuca idahoensis*, and *Stipa thurberiana*. These two major sagebrush types can be viewed as contrasting endpoints of a structural continuum that varies along gradients of effective soil moisture and disturbance history. Sagebrush ecosystems are particularly important landscape components at DINO, CURE, HOVE, FOBU, and BLCA. Sagebrush-dominated ecosystems of the Intermountain West have been severely impacted by land-use activities. Good-condition representatives of this ecosystem type are scarce and considered critically imperiled on a regionwide basis (Noss et al. 1995). For this reason, healthy sagebrush ecosystems are among the most significant natural resources of NCPN units.

-Pinyon-Juniper Woodlands: coniferous woodlands dominated by various species of pinyon and juniper are widespread across the Colorado Plateau (West and Young 2000, McPherson 1997). *Juniperus osteosperma* and *Pinus edulis* are the dominant taxa in NCPN units, although *P. monophylla* also occurs at ZION. Both juniper and pinyon are substrate generalists capable of establishing in rocky soils derived from a wide range of geologic parent materials (Harper and Davis 1999, West and Young 2000). However, understory components of this community type are strongly affected by substrate characteristics, resulting in considerable compositional variation among assemblages broadly grouped together as "pinyon-juniper woodlands" (West and Young 2000). Though heterogeneous, pinyon-juniper woodland is the most common ecosystem of the NCPN.

-Biological Soil Crusts: biological soil crusts composed of cyanobacteria, mosses, lichens, liverworts, microfungi, and green algae are significant components of most arid-semiarid ecosystems. Where they occur undisturbed, biological soil crusts are major contributors to ecosystem function (soil stability, nutrient cycling, hydrologic function) and biodiversity (Belnap and Lange 2001). Biological soil crusts have been described as "ecosystem engineers" because of their disproportionate effects on the structure and function of arid-semiarid ecosystems (Jones et al. 1994). As a consequence of their contributions to ecosystem function and diversity, biological soil crusts are among the most significant NCPN natural resources.

Montane Shrubland, Coniferous Woodland, and Forest Ecosystems

-Montane Shrublands: transitional between pinyon-juniper woodlands and lower montane coniferous forests, these mostly deciduous shrublands typically are dominated by *Quercus gambelii*, *Cercocarpus montanus*, *C. ledifolius*, *Amelanchier* spp., *Symphoricarpos* spp., and *Purshia* spp. Evergreen oaks (e.g., *Q. turbinella*) enter this association at the southern margin of the NCPN at ZION. This ecosystem is a landscape dominant at BLCA and is common at several other NCPN units. This type of deciduous shrubland has also been referred to as petran chaparral and Great Basin montane scrubland (Brown 1982, Floyd et al. 2000).

-Ponderosa Pine Woodlands and Forests: dominated by *Pinus ponderosa*, this is the most extensive type of ecosystem in the Mogollon Rim region of the southern Colorado Plateau and is common in the lower montane zones on mountains elsewhere on the Plateau (Peet 2000). Tree density and understory composition in this type are strongly dependent on disturbance history. Ecosystems dominated by *P. ponderosa* are most extensive at BRCA (Stein 1988), ZION (Madany and West 1983), DINO, and CURE.

-Douglas Fir Forests: dominated by *Pseudotsuga menziesii*, this forest type often replaces *Pinus ponderosa* forests successionally in the absence of fire, and spatially along a gradient of increasing soil moisture (Peet 2000). Thus ecosystems structurally dominated by *P. menziesii* typically intergrade with those dominated by *Pinus ponderosa* in relation to disturbance history and topographic aspect. Among NCPN units, *P. menziesii* ecosystems are most extensive at BRCA, ZION, and DINO. At CANY and several other relatively low-elevation parks, isolated stands of *P. menziesii* commonly are found in favorable microsites at the bases of north-facing cliffs.

-Aspen Forests: dominated by *Populus tremuloides*, these forests often replace those dominated by *Pinus ponderosa* and/or *Pseudotsuga menziesii* following fire and are subsequently replaced again by the conifers following long fire-free periods (Peet 2000). On the Colorado Plateau, clonal aspen populations appear to have dominated some high-

elevation shale-derived soils for thousands of years without replacement by conifers, possibly due to conifer intolerance of clay soils (Betancourt 1990).
Extensive stands of *Populus tremuloides* are uncommon in the NCPN, but sparse isolated stands are found in many parks. This type of ecosystem is most extensive at FOBU.

-Montane Meadows and Shrubland Parks: dominated by herbaceous vegetation and/or low shrubs (e.g., *Artemisia nova*), this ecosystem type is typically interspersed with forested ecosystems. Several hypotheses have been posed to explain the persistent presence of herb- and/or shrub-dominated vegetation in the midst of otherwise forested landscapes. In general, most montane meadows are associated with edaphic, disturbance, or air-drainage patterns that constrain tree recruitment (Peet 2000). In the NCPN, montane meadows and shrubland parks are important landscape components at CEBR and BRCA.

-Spruce-Fir Forests: characteristic of the subalpine zones of Colorado Plateau mountains and the Rocky Mountain region generally, these forests typically are dominated by *Picea engelmannii* and *Abies lasiocarpa* (Peet 2000). Among NCPN units, these forests are most extensive at CEBR, BRCA, and on north-facing canyon slopes at TICA. Sparse spruce-fir communities also are found on steep canyon slopes at BLCA and in favorable canyon microsites both at BLCA and CURE.

-Subalpine Woodlands: dominated by sparse stands of *Pinus longaeva* (western bristlecone pine), these ecosystems typically occur on high-elevation ridges exposed to desiccating winds or on high-elevation exposures of calcareous geologic substrates; frequently, these two factors coincide. *Pinus flexilis* (limber pine) may also occur in this woodland ecosystem. Soils are skeletal and under-story vegetation uncommon (Buchanan 1992). In contrast with the other montane ecosystems in this group, fire is relatively unimportant as a natural disturbance in these sparse woodland ecosystems (Bradley et al. 1992). Among NCPN units, bristlecone-limber pine woodlands occur primarily at CEBR and BRCA where they are associated with exposed ridges and cliff faces of the Claron Formation. At CARE, this ecosystem is found on high-elevation exposures of the Carmel Formation.

<u>Riparian, Wetland and Aquatic Ecosystems</u>
Riparian, wetland and aquatic ecosystems are important contributors to landscape-level diversity, ecological integrity, and connectivity of NCPN units. As a consequence, they are clearly among the most significant natural resources of this predominantly arid network. The structure, function and sustainability of these keystone ecosystems depend fundamentally on the quality and quantity of water resources. The ecological significance of water resources cannot be overemphasized. Brief descriptions of aquatic, riparian and wetland ecosystems follow, including discussions of impaired and pristine waters of the NCPN. Significant waters identified by park staff are listed in Table 7 and described in greater detail in park-specific water-resource descriptions in Appendix R.

-Slickrock Potholes and Waterpockets: deep weathering pits formed in sandstone support unique aquatic ecosystems of varying longevity. These range from truly ephemeral

systems that emerge and disappear in relation to individual precipitation events, to deep aquatic systems that persist for months or indefinite long periods of time.
Slickrock potholes are particularly characteristic of sandstone exposures found at ARCH, CANY, CARE, and ZION.

-Hanging Gardens: these unique, insular riparian and aquatic ecosystems located in rock alcoves and beneath canyon pour-offs are diverse and productive (Welsh and Toft 1981, Fowler 1995). Common vascular plants include *Adiantum capillus-veneris*, *Petrophytum caespitosum*, *Epipactis gigantea*, *Carex aurea*, and *Mimulus* spp. Several Colorado Plateau endemics are found almost exclusively in hanging gardens, including *Primulus specuicola* and *Cirsium rydbergii*. Although hanging gardens are found in most NCPN units, the distribution, characteristics, and potential threats to these ecosystems have not been well documented. Because of their diversity and distinctive characteristics, hanging gardens are among the most significant natural resources of the NCPN.

Table 7. Significant water bodies identified by parks, Northern Colorado Plateau Network.

Park	Perennial streams (no.)	Intermittent streams (no.)	Ponds (no.)	Reservoirs (no.)	Mapped springs (no.)	Unmapped springs (est. no.)	Hanging gardens (est. no.)	Water pockets (est. no.)	303(d) list*	ONRW**	Significant water bodies	Comments
ARCH	1	7	0	0	13	unk.	unk.	unk.	none	none	Salt Wash (perennial), Courthouse Wash, Freshwater Canyon, Sleepy Hollow, Seven Mile Canyon, Salt Valley Wash, Salt Wash, Salt Spring, Willow Spring, Lost Spring Canyon	
BLCA	1	3	0	0	0	unk.	unk.	none	Red Rock Creek	pending	Gunnison R. below Aspinall, Red Rock Cr., Grizzly Gulch, Deadhorse Gulch	Park notes impaired condition of Red Rock Cr., 3 reservoirs on Grizzly Gulch
BRCA	0	7	0	0	13	unk.	none	none	none	none	East Cr., Yellow Cr., Sheep Cr., Bryce Cr., Swamp Canyon, Campbell Cr., Podunk Cr.	
CANY	3	8	0	0	122	unk.	unk.	unk.	none	none	Green R., Colorado R., Salt Cr., Davis Canyon, Lost Canyon, Little Spring Canyon, Horseshoe Canyon, Lavender Canyon, Jasper Canyon, Squaw Canyon, Water Canyon	
CARE	4	4	0	0	3	unk.	unk.	unk.	Fremont River	none	Fremont R., Sulphur Cr., Pleasant Cr., Oak Cr., Halls Cr., Polk/Bulberry Cr., Deep Cr., Middle Desert Wash, waterpockets & springs	
CEBR	1	5	1	0	0	unk.	none	unk.	none	none	Blowhard Spring, Shooting Star Spring, Twin Spring, Sunset Spring, Unnamed Spring	
COLM	0	5	0	0	0	unk.	unk.	unk.	none	none	None named	

Table 7 cont.

Park	Perennial streams (no.)	Intermittent streams (no.)	Ponds (no.)	Reservoirs (no.)	Mapped springs (no.)	Unmapped springs (est. no.)	Hanging gardens (est. no.)	Water pockets (est. no.)	303(d) list*	ONRW**	Significant water bodies	Comments
CURE	20	unk.	0	3	0	unk.	unk.	none	none	pending	Gunnison R. above and below reservoirs; Blue Mesa, Morrow Point, and Crystal reservoirs; Cimarron R., N. and S. Beaver Cr., Steuben Cr., Stevens Cr., N. Willow Cr., West Elk Cr., East Elk Cr., Soap Cr., Cebolla Cr., Lake Fork of the Gunnison R., Pine Cr., Blue Cr., Curecanti Cr., Corral Cr., Round Coral Cr., Mesa Cr., Crystal Cr., Myer's Gulch, Pool Gulch, Red Cr., canyon springs and seeps	
DINO	2	unk.	unk.	0	36	unk.	unk.	unk.	none	none	Green and Yampa rivers, streams and springs	
FOBU	0	3	0	0	0	unk.	none	none	none	none	Spring #1, Spring #2, Millet Canyon, Murder Hill Canyon, Moosebones Canyon, Cundick Spring	
GOSP	1	0	0	0	0	none	none	none	none	none	Blue Cr.	
HOVE	0	4	0	0	1	unk.	none	none	none	none	Little Ruin Canyon, Hackberry Canyon, Cajon Spring, Cutthroat Canyon, Goodman Point Canyon	
NABR	0	4	0	0	1	unk.	unk.	unk.	none	none	Tuwa Canyon, White Canyon, Armstrong Canyon, To-ko-chi Canyon, seeps	
PISP	0	0	2	0	0	none	unk.	none	none	none	Main Spring, Fort Spring, Ponds, Tunnel Spring, West Cabin Spring	
TICA	1	0	3	0	0	none	none	none	none	none	American Fork R., Timpanogos Cave pools	
ZION	9	unk.	unk.	0	9	100s	16	unk.	North Creek	none	N. and E. Fork Virgin rivers, Kolob Cr., Pine Cr., Orderville Canyon, Deep Cr., Shunes Cr., North Cr., La Verkin Cr., waterpockets and hanging gardens	Utah DEQ will attempt to remove North Cr. within park from 303(d) - data do not support listing.

-Perennial Wetlands: ecosystems with vegetation dominated by sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and cattails (*Typha* spp.) are present but uncommon on the Colorado Plateau (West and Young 2000). Because of their comparative rarity and diversity, as well as their association with surface water, wetland ecosystems possess particularly high conservation value.

-Reservoirs: Although artificial in nature, these aquatic ecosystems are important resources that support diverse biotic assemblages and high levels of recreational use. In the NCPN, this type of ecosystem is found only at CURE.

-Rivers and Streams with Associated Aquatic and Riparian Ecosystems: in terms of spatial extent, rivers and streams with their associated aquatic and riparian ecosystems are relatively minor landscape components in most NCPN units. However, where present, these ecosystem complexes contribute disproportionately to the diversity, integrity, and conservation value of NCPN landscapes. At low and intermediate elevations across the Colorado Plateau, *Populus fremontii* and *Salix exigua* dominate streamside riparian woodlands (MacMahon 1988). In many drainages, these native cottonwoods and willows face considerable competition from exotic *Tamarix* spp. and *Elaeagnus angustifolia*. At higher elevations, *Populus angustifolia, Alnus* spp., *Acer negundo, Betula occidentalis, Shepherdia argentea*, and several *Salix* spp. dominate comparable riparian ecosystems (Peet 2000). Major rivers that flow through or adjacent to NCPN units include the Colorado River (CANY and ARCH), the Gunnison River (BLCA and CURE), the Fremont River (CARE), the Yampa and Green Rivers (DINO), the American Fork River (TICA), and the Virgin River (ZION). Aquatic and forested riparian ecosystems associated with large streams and rivers are among the most critically endangered ecosystems in the nation, and they have been particularly impacted by land-use activities in the arid-semiarid West (Noss et al. 1995). Because of their importance to individual parks as well as their degree of national imperilment, these ecosystems have been identified as among the most significant natural NCPN resources.

Description of 303d Waters in NCPN Park Units

Under the Clean Water Act (CWA), states must identify all waters that do not meet or are not expected to meet water quality standards. The identification and public notification of water-quality-limited waters is accomplished through what has become known as "303(d) lists" after the CWA section where the requirement is contained (NPS 2001a). States are required to perform an analysis of the cause(s) of this non-attainment of standards and develop a plan for bringing the problem water body into compliance. These plans analyze the Total Maximum Daily Loading of contaminants to the water and are therefore referred to as "TMDL" plans. States can consider a wide variety of remedies including reducing the contaminant loading, changing the designated protected uses (such as from Cold Water Fishery to Warm Water Fishery) to more accurately reflect ambient conditions, or documenting that the "poor" quality of the water is due to natural causes and is not correctable.

Three water sources in parks in the NCPN have been reported on the non-attainment or 303d list (Fig. 5). These are:

North Creek in ZION is listed for Total Dissolved Solids with 39% of samples between 1996 and 2002 exceeding the 1,200 mg/l standard. A TMDL analysis has been completed for North Creek, concluding that the high dissolved solids are primarily the result of natural conditions with minor contributions from agricultural runoff. The state will prepare a use attainability analysis to determine if the problem can be corrected, and if not suggest a new standard specific to this creek.

The Fremont River Upstream of CARE has had a TMDL analysis completed (September 2002) for total Phosphorus, Organic Enrichment and Low Dissolved Oxygen. The TMDL report identified numerous livestock feeding operations and other agricultural practices as contributors to the nutrient loading. Though the river segment found to not support the designated beneficial use ends at the park boundary, the affected water flows into the park. State monitoring at found the river to routinely exceed the standard for total phosphorus at Hickman Bridge inside the park. Additionally, a TMDL report has been completed for the Fremont River segment immediately downstream of the park for high salinity, total dissolved solids and chlorides. Both river segments are currently Category 4A, for waters that are impaired and have a completed TMDL.

Red Rock Creek in BLCA was recently added to the 303d list along with all “Gunnison River Tributaries between Crystal Creek and the Colorado River (not including USFS land)” for high selenium. The TMDL analysis for these waters is a high priority but has not been initiated at this time. Selenium is a widespread problem in the upper Colorado River Basin, in particular in streams that drain Mancos shale geology. Agricultural runoff from irrigated lands increases the contribution of selenium.

Additional waters of concern near NCPN units:

Kolob Reservoir upstream of ZION has been assigned category 5D by the Utah DEQ, meaning that it has been intermittently out of compliance for Dissolved Oxygen during some monitoring cycles, but not others. Should it be out of compliance for two consecutive monitoring periods it would be moved to the 303d list and be subject to a TMDL analysis? This reservoir is upstream of Zion National Park. The degree of concern on the part of the park for low dissolved oxygen is relatively low because the stream flows over numerous waterfalls as it descends over 3,000 feet in 7 miles of channel, so should be well oxygenated throughout.

Blue Creek upstream of GOSP is subject of a TMDL review of industrial discharges upstream of the park. The state of Utah categorizes it as a “5C” water, meaning that the permitted discharge loading to the stream is significant and requires TMDL analysis.

-Pristine Waters: the highest level of water-quality protection under standards associated with the CWA applies to certain waters that constitute an outstanding state or national resource. These waters, which are those designated as Outstanding Natural Resource Waters (ONRWs), shall be maintained and protected at their existing quality. Waters qualify for ONRW status if they are a significant attribute of a State Gold Medal Trout

Fishery, a national park, national monument, national wildlife refuge, a designated wilderness area, are part of a designated wild river under the Federal Wild and Scenic Rivers Act, or the waters have exceptional recreational or ecological significance, and have not been modified by human activities in a manner that substantially detracts from their value as a natural resource. A nomination and designation process is required to obtain administrative designations of ONRW status (NPS 2001a).

Currently, no NCPN parks have waters with designated ONRW status. However, BLCA and CURE are pursuing ONRW status for selected high-quality waters. These parks have collected water-quality data since the 1980s as part of a baseline water-quality monitoring program. These data are being used to determine constituent fluxes into the reservoir system and to characterize existing water-quality conditions in an area experiencing rapid increases in land-use intensity, population, and recreational use. Based on limited data and types of constituents collected, certain streams and rivers have shown existing water quality that is of higher quality than standards directed by the CWA and enacted by Colorado. Recent explosive and potential future growth surrounding these parks has prompted an investigation into the feasibility of attaining ONRW status for selected waters. This designation will protect the waters of BLCA and CURE beyond current standards, consistent with Servicewide and park guidelines.

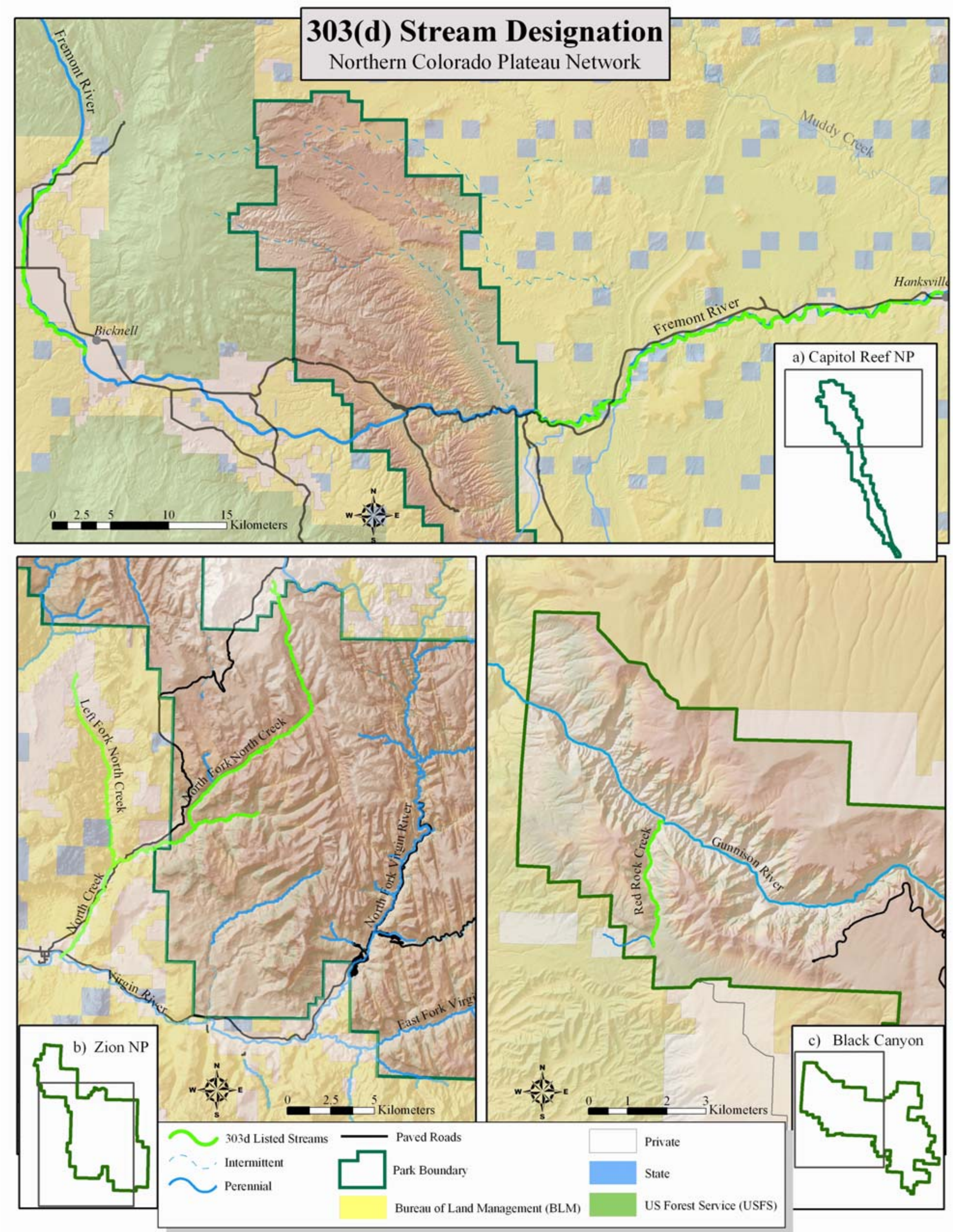


Figure 5. Reaches of the Fremont River near Capitol Reef National Park (a), of North Creek in Zion National Park (b), and Red Rock Creek in Black Canyon (c) that currently are listed as water-quality impaired on Utah 303(d) list (Utah DEQ 2002) and Colorado.

Table 8. Approximate taxonomic richness of Northern Colorado Plateau Network parks and monuments. Values were derived from the number of occurrences in the NPSpecies database and include all taxa that were annotated as confirmed, probably present, unconfirmed, or historic as of 8/16/02.

	Approximate richness by taxonomic group						
Park code	Vascular plants	Fish	Amphibians	Reptiles	Birds	Mammals	TOTAL
ARCH	475	31	9	22	207	74	818
BLCA	265	14	8	14	160	75	536
BRCA	461	1	7	16	217	79	781
CANY	628	31	10	25	218	81	993
CARE	1092	8	7	21	228	84	1440
CEBR	279	1	3	11	143	71	508
COLM	331	0	8	19	147	66	571
CURE	339	16	4	8	192	74	633
DINO	588	31	7	18	244	74	962
FOBU	524	0	6	9	178	75	792
GOSP	120	0	6	17	103	80	326
HOVE	274	0	9	23	147	71	524
NABR	431	0	10	25	208	76	750
PISP	165	1	9	26	78	70	349
TICA	247	3	4	15	164	75	508
ZION	922	9	10	47	262	87	1337

Species

Estimated richness of vascular plants and vertebrates varies considerably among NCPN units (Table 8). CARE and ZION have the largest known floras; DINO, CANY, and ARCH have the most fish taxa; CANY, NABR, and ZION have the most amphibians; ZION by far has the most reptile taxa; ZION, DINO, and CARE have the most birds; and ZION and CARE have the most mammals. Combined richness in these groups is greatest at ZION and CARE. Previous work investigating patterns of floristic richness on the Colorado Plateau has found vertical relief to be the single environmental variable most positively correlated with the number of vascular plants documented for particular land units (J. Spence, personal communication). In the NCPN data set, floristic richness is also significantly correlated with vertical relief ($r = 0.75$, $p < 0.05$), probably because vertical relief serves as a coarse indicator of habitat diversity.

Floristic Distinctiveness

The Colorado Plateau is a center of plant speciation and endemism. Although no attempt has been made to determine the size of the flora, there are an estimated 2500-3000 species. About 10 percent of this flora is endemic (Schultz 1993), consisting mostly of herbaceous dicots in the genera *Astragalus*, *Cryptantha*, *Erigeron*, *Eriogonum*, *Gilia*, *Phacelia*, and *Penstemon*. Holmgren (1972) described floristic sections of the Intermountain Region and observed that the Canyonlands floristic section, which in part coincides with the Northern Canyonlands Section (Fig. 4), is by far the richest part of the Intermountain Region in terms of plant endemism. The Uinta Basin and the Utah High Plateaus and Mountains sections also have relatively high numbers of narrow endemics. Notably, many of the Utah High Plateau endemics are restricted almost entirely to the Claron Formation, which is exposed so dramatically at CEBR and BRCA (Utah Division of Wildlife Resources 1998).

The Claron example supports the important generalization that plant endemism on the Colorado Plateau is highly correlated with the exposure of raw geologic substrates or unweathered colluvium (Welsh 1978, 1979, Welsh et al. 1993). In the Uinta Basin and Northern Canyonlands sections, geologic substrates that support disproportionately high numbers of narrow endemics include shales, siltstones, mudstones, and sandstones, as well as materials derived from these (Welsh 1979). Important geologic formations in terms of endemic plants include many of those shared by NCPN parks (Table 1): Cedar Mesa, Cutler, Moenkopi, Chinle, Navajo, Carmel, Entrada, Morrison, Dakota, Mancos / Tropic, and Claron (Welsh 1979).

Through quantitative analyses of local floras of the western United States, McLaughlin (1986, 1989, and 1992) recognized the existence of a distinct Colorado Plateau floristic subprovince. Within the Colorado Plateau subprovince, he recognized a northern Colorado Plateau floristic district and a southern Colorado Plateau floristic district based on the occurrence and range of narrowly distributed species (endemics). Of NCPN units, DINO, CANY, CARE, ARCH, HOVE, and COLM were in the area delimited as the northern Colorado Plateau floristic district, whereas BRCA, ZION, NABR, and PISP were in the southern Colorado Plateau floristic district. Remaining NCPN units were placed in one of several surrounding floristic districts.

Conservation Status

Based on information in the NPS Endangered Species Program database as of June 2002, 25 taxa with Federal Endangered Species Act (ESA) status are considered by park staff to occur in NCPN parks or monuments (Table 9). These include 1) taxa that are currently listed as threatened or endangered, 2) taxa that are candidates for listing, 3) taxa that recently have been delisted, and 4) taxa that are managed under conservation agreements with the U.S. Fish and Wildlife service but are not listed as threatened or endangered. Among the 25 taxa are 11 vascular plant species, five fish species, one reptile species, seven bird species, and one mammal species. Most listed plants are rare edaphic endemics. Taxa with the widest distribution among NCPN parks are the recently delisted American peregrine falcon (*Falco peregrinus anatum*) and the bald eagle (*Haliaeetus leucocephalus*)—a taxon proposed for delisting. Similar to the general patterns in species richness described above, CARE and ZION have the largest numbers of listed taxa in the NCPN (Table 10).

Tables 9 and 10 understate the number of rare and sensitive species that occur in (or potentially occur in) NCPN parks. For example, DINO and CARE each have over 40 vascular plant taxa that are considered sensitive by park staff. These are primarily rare edaphic endemics with conservation ranks of G3 and above (see footer to Table 9 for explanation of heritage conservation ranks and codes). Relatively large numbers of rare plant taxa also are found at ARCH, CARE, CANY, BRCA, and ZION. The NCPN is currently working to develop a standard approach for determining sensitive species on a networkwide basis.

In addition to these rare but unlisted taxa, several listed or candidate taxa could potentially occur in NCPN units where they have not yet been documented. Examples include the southwestern willow flycatcher (*Empidonax traillii extimus*) at ARCH and CANY and the Gunnison sage grouse (*Centrocercus minimus*) at HOVE and COLM.

Temporal Patterns of Ecosystem Change: Pleistocene to Current

Paleoecological studies allow extant terrestrial ecosystems to be viewed in a broader temporal context. For example, late-Pleistocene alpine glaciers probably occupied the current site of CEBR until about 13,000 years ago (13 ka) (Anderson et al. 1999). Pollen and macrofossils in sediment cores suggest that subalpine coniferous forests dominated by *Picea* (spruce) and *Abies* (fir) became established at current elevations in the Utah High Plateaus and Mountains by about 9.8 ka. With some fluctuations, *Picea-Abies* forests generally have dominated high Plateau ecosystems throughout the Holocene.

Plant macrofossils collected from *Neotoma* (packrat) middens provide a rich record of late-Pleistocene and Holocene environments at lower elevations across the Plateau. The Pleistocene-Holocene biogeography of the Colorado Plateau, as reflected by *Neotoma* middens, has been well described by Betancourt (1984, 1990); the following draws from his work. Relative to present, late-Pleistocene (13-10 ka) vegetation patterns were characterized by several distinctive features. Based on the absence of *Pinus ponderosa* (ponderosa pine) and *P. edulis* (pinyon pine) macrofossils from late-Pleistocene midden sequences, these two species were evidently displaced southward and completely absent from the Plateau as recently as 10 ka. During the late Pleistocene, montane coniferous woodlands dominated by *Pinus flexilis* (limber pine), *Juniperus scopulorum* (Rocky Mt. juniper), *Pseudotsuga menziesii* (Douglas-fir), *Picea pungens* (blue spruce), *Abies concolor* (white fir), and *Juniperus communis* (common juniper) probably occurred at elevations and landscape positions similar to those where *Juniperus osteosperma* and *Pinus edulis* are found today. Because of the absence of *P. ponderosa* and *P. edulis*, these late-Pleistocene coniferous woodlands would have occurred directly above *J. osteosperma* woodlands and arid-semiarid shrublands. The record provided by *Neotoma* middens clearly supports the ecological principle that species respond individualistically to environmental factors (including Pleistocene-Holocene climate changes) rather than as synchronized members of distinct plant communities. Thus many species assemblages of the late Pleistocene (e.g., *Picea pungens*, blue spruce, with *Atriplex canescens*, four-wing saltbush) have no modern counterparts. Relative to modern distributions, it can be said that individual species were elevationally displaced by 200–800 m during the late Pleistocene. Few, if any generalizations can be made concerning elevational displacements of intact biotic communities. Species assemblages and distributions that we now recognize as “modern vegetation” were established by about 3.4 ka on the Colorado Plateau.

Paleoecological studies conducted at ARCH generally support the scenario described above (Sharpe 1993). Evidence from *Neotoma* middens indicates that *Pinus flexilis* and *Pseudotsuga menziesii* dominated late-Pleistocene vegetation in a rock alcove currently

vegetated by *Juniperus osteosperma*, *Pinus edulis*, *Quercus gambelii*, various cacti, and herbaceous plants.
Relative to their current distributions, late-Pleistocene elevational displacements of *P. flexilis* and *P. menziesii* were 513 m and 208 m, respectively. Modern vegetation was established near the alcove prior to 2.7 ka.

In *Neotoma* midden studies conducted at CARE, Cole and colleagues (1997) concluded that the greatest vegetation changes evident in their 5400-year midden record were those that occurred during the past 200 years. They attributed the recent magnitude of vegetation changes to 19^{th}-century grazing by sheep and cattle following Euro-American settlement. Livestock-palatable species such as *Stipa hymenoides* and *Ceratoides lanata* were consistently present throughout the pre-settlement midden record. These and several species palatable to sheep but not cattle were markedly absent in samples dated to the post-settlement period. Several species considered indicative of overgrazed rangelands were not present in the pre-settlement record but were abundant in the post-settlement record.

The research conducted by Cole and colleagues (1997) is instructive in its conclusion—current ecosystem conditions at CARE reflect the long-lived legacy of past and ongoing land-use activities. Although methods applied in this study are somewhat unusual, conclusions are not. Most NCPN units manage ecosystems that have been significantly altered by past and/or ongoing human activities. In many of these ecosystems, the “abnormal conditions” referred to in the Servicewide goals for vital signs monitoring were triggered and realized long ago. The existence of already-abnormal conditions presents challenges for the monitoring program, and suggests the need for explicit inventories of ecosystem conditions and restoration needs in conjunction with the development of the monitoring plan.

Table 9. Taxa with federal Endangered Species Act status (i.e., currently listed, candidates for listing, recently delisted, or managed under conservation agreements) that are considered by park staff to occur currently in Parks or Monuments of the Northern Colorado Plateau Network. Table is based on information in the NPS Endangered Species Program database as of June 2002. See table 10 for counts of listed taxa by park.

Taxonomic group Scientific name	Common name	Heritage Conservation Status*	Endangered Species Act Status**	Parks	Comments
Vascular plants					
Salix arizonica	Arizona willow	G2G3S2	M	CEBR	
Pediocactus despaini	Despain's cactus	G2	E	CARE	
Cycladenia humilis var. *jonesii*	Jones' cycladenia	G3G4T2	T	CARE	Chinle Fm.
Townsendia aprica	Last Chance townsendia	G2	T	CARE	Clay soils in Mancos & several other shale formations.
Erigeron maguirei	Maguire daisy	G2	T	CARE	Navajo Fm.
Astragalus eremiticus var. ampullarioides	Shivwits Milkvetch	G1S1Q	E	ZION	Chinle Fm.
Schoenocrambe barnebyi	Sye's Butte plainsmustard	G2	E	CARE	Moenkopi Fm.
Spiranthes diluvialis	Ute ladies' tresses	G2	T	CARE, DINO	
Pediocactus winkleri	Winkler's pin-cushion cactus	G2	T	CARE	Morrison & Dakota Fms.
Gilia caespitosa	Wonderland Alice-flower	G2	C	CARE	Navajo Fm.
Sclerocactus wrightiae	Wright fishhook cactus	G2	E	CARE	
Fish					
Gila elegans	Bonytail chub	G1	E	CANY, DINO	
Ptychocheilus lucius	Colorado pikeminnow	G1	E	CANY, DINO	
Gila cypha	Humpback chub	G1	E	CANY, DINO	
Xyrauchen texanus	Razorback sucker	G1	E	CANY, DINO	
Lepidomeda mollispinis	Virgin spinedace	G1	M	ZION	
Reptiles					
Gopherus agassizii	Desert tortoise	G4S1	T	ZION	
Birds					
Falco peregrinus anatum	American peregrine falcon	G4	DM	BLCA, BRCA, CARE, COLM, CURE, DINO, ZION	
Haliaeetus leucocephalus	Bald eagle	G4	T, AD	ARCH, BLCA, BRCA, CANY, CARE, COLM, CURE, DINO, GOSP, HOVE, ZION	
Gymnogyps californianus	California condor	G1	EXPN	ARCH, BRCA	
Centrocercus minimus	Gunnison sage grouse	G1	C	BLCA, CURE	
Strix occidentalis lucida	Mexican spotted owl	G3T3	T	BRCA, CANY, CARE, DINO, ZION	Not confirmed in BRCA, but surveys conducted for USFWS Endangered Species Act Sect. 7 projects.
Empidonax traillii extimus	Southwestern willow flycatcher	G5T2	E	BRCA, CARE, ZION	Not seen in BRCA since 1996.
Coccyzus americanus	Yellow-billed cuckoo	G5S1	C	CARE, ZION	
Mammals					
Cynomys parvidens	Utah prairie dog	G1	T	BRCA	

Table 10. Numbers of taxa with federal Endangered Species Act status (i.e., currently listed, candidates for listing, recently delisted, or managed under conservation agreements) that are considered by park staff to occur currently in Parks or Monuments of the Northern Colorado Plateau Network. Table is based on information in the NPS Endangered Species Program database as of June 2002. See Table 8 for identities of taxa in each park.

	Number of taxa by taxonomic group						
Park code	Vascular plants	Fish	Amphibians	Reptiles	Birds	Mammals	TOTAL
ARCH	-	-	-	-	2	-	2
BLCA	-	-	-	-	3	-	3
BRCA	-	-	-	-	5	1	6
CANY	-	4	-	-	2	-	6
CARE	9	-	-	-	5	-	14
CEBR	1	-	-	-	-	-	1
COLM	-	-	-	-	3	-	3
CURE	-	-	-	-	3	-	3
DINO	1	4	-	-	3	-	8
FOBU	-	-	-	-	-	-	-
GOSP	-	-	-	-	1	-	1
HOVE	-	-	-	-	1	-	1
NABR	-	-	-	-	-	-	-
PISP	-	-	-	-	-	-	-
TICA	-	-	-	-	-	-	-
ZION	1	1	-	1	5	-	8

Paleontological Resources

Geologic features are important controls of contemporary ecological patterns, but they also reflect environments of the long-distant past. Paleontological objects and features—remnant signs of life from that long-distant past—are also among the outstanding natural resources of NCPN units. DINO and FOBU were established precisely because of their wealth of paleontological resources, and many other network parks possess valuable resources of this type. In addition to DINO and FOBU, other network parks with significant paleontological resources include ARCH, BLCA, BRCA, CANY, CARE, COLM, CURE, HOVE, NABR, and ZION. The fossil-rich Morrison Formation which supports the dinosaur quarry at DINO is also exposed at ARCH, BLCA, CARE, COLM, CURE, and HOVE (Table 1).

Sensory Resources

In an increasingly urbanized world, sensory (or aesthetic) resources are among the most precious and valued resources of network parks. Sensory resources include nightskies populated by crystal-clear points of undiminished starlight and moonlight; soundscapes rich with unobscured sounds of organisms, wind, and water; and expansive, uncluttered, far-reaching viewscapes with clean air; and solitude. To varying degrees, these resources are important and outstanding characteristics of all network parks.